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RESEARCH

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Optimizing surgical precision: a comparative study of three-port vs. four-port robotic-assisted lobectomy for NSCLC

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Abstract

Background In recent years, robot-assisted thoracoscopic surgery has seen major advances. The feasibility and safety of this new surgical procedure have been widely recognized. However, only a few studies have investigated the short-term postoperative outcomes of lobectomy in early-stage non-small cell lung cancer (NSCLC) patients using different numbers of ports in Da Vinci robot-assisted surgery. This study aimed to evaluate the clinical value of robot-assisted lobectomy by comparing the perioperative data of NSCLC patients who underwent three-port and four-port surgical methods.

Methods The data of 121 consecutive patients who were admitted to our hospital for NSCLC and underwent Da Vinci robot-assisted thoracic surgery (RATS) for radical resection from January 2020 to October 2021 were retrospectively collected and analyzed. The cases that did not meet the inclusion criteria were removed, and the patients were divided into the three-port group (76 cases) and the four-port group (45 cases). The general clinical data, perioperative data, and postoperative pain were individually compared to determine the different clinical effectiveness of the two approaches.

Results All 121 patients in the 2 groups successfully underwent lobectomy and systemic lymph node dissection. No significant difference in age, sex, tumor location, tumor size, history of chronic disease, pathological type, pathological tumor-node-metastasis (pTNM) staging, postoperative complications, and number or stations of total lymph nodes dissected was observed between the two groups ($P > 0.05$). The operation time [(117.32 ± 36.55) min vs. (136.83 ± 40.63) min], the console time [(90 ± 19.35) min vs. (103 ± 15.65) min], the intraoperative blood loss [(94.34 ± 32.16) mL vs. (102.73 ± 33.67) mL], the chest tube drainage time [(2.43 ± 0.65) d vs. (2.79 ± 1.42) d], and the postoperative hospitalization time [(4.55 ± 1.43) d vs. (5.14 ± 1.66) d] were lower in the three-port group compared to the four-port group but showed no statistically significant difference ($P > 0.05$). However, the three-port group

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demonstrated significantly superior visual analogue scale pain scores compared to the four-port group at 24, 48, and 72 h postoperatively (all $p < 0.001$).

Conclusions Compared to four-port RATS, the three-port robotic-assisted lobectomy is safe, practicable and effective. Operative incision optimization leads to less postoperative pain and appears to be more acceptable for patients with NSCLC.

Keywords Robot-assisted thoracic surgery (RATS), Lobectomy, Three Port, Four Port, Non-small cell lung cancer (NSCLC)

Introduction

Lung cancer has been reported to be the leading cause of cancer mortality, with the highest rate of morbidity and mortality among all malignant tumors worldwide [1]. In the treatment of lung cancer, lobectomy with lymph node dissection remains the cornerstone [2]. As many patients opt for minimally invasive surgery, such as video-assisted thoracoscopic surgery (VATS), rather than traumatic open thoracotomy. Meanwhile, the number and the size of surgical incisions are taken into consideration, resulting in the development of bi-port and uni-port thoracic surgery, which has led to a lot of clinical innovations and research.

The first robotic surgical system was introduced into the operating room in 1999 [3]. Robotic-assisted thoracic surgery (RATS) represents the evolution of VATS by proposing a high-resolution magnification of the 3-dimensional (3D) surgical field [4], tremor reduction [5], and precise manipulation of multi-joint forceps in multiple directions [6]. In addition to the advantages mentioned above, many studies have reported that RATS provides a safer and more feasible approach than VATS, offering a smaller incision size, lower postoperative pain, more effective lymph node (LN) dissection, and shorter postoperative recovery time [7, 8].

Currently, RATS is widely accepted and increasingly used in the surgical treatment of patients with NSCLC; however, there is no unified standard for incision design and strategy in robot-assisted thoracoscopic lobectomy. Almost all the robotic procedures for anatomical lung resection are relatively fixed to 3–4 arms and utilize multi-port patterns, such as 4–5 ports [9–11]. Postoperative pain may be reduced and life quality improved by employing fewer incisions, which may also lower the associated cost due to using fewer arms [12]. Four-port RATS (three arms and one assistant hole) was the most common surgical approach, which was consistent with the triangle target principle proposed by Sasaki M [13]. Considering the decreasing trend in the number of surgical incisions in VATS from multi-, tri-, bi-, to uni-port, our research group adopted the three-port method to utilize a lower incision count in robot-assisted lobectomy and segmentectomy, as reported in 2022 [5, 6]. Meanwhile, few articles have reported the utilization of the three-port approach [12], the adoption of which is held back by complex surgical techniques. To the best of our knowledge, no study has compared the clinical effects of three-port and four-port RATS surgical procedures. Therefore, this study aimed to compare the surgical outcomes of these two groups in the treatment of robotic lobectomy for NSCLC. Furthermore, this research offers guidance on three-port RATS lobectomy in clinical practice and expands the application of the three-port robot-assisted surgical approach.

Materials and methods

Study design and surgical indications

This retrospective comparative study was performed in the thoracic surgery department of the Third Affiliated Hospital of Soochow University and was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of the hospital (No. 2021 technology 97). Informed consent was obtained from all the patients for the research and publication of the associated results. The indications and contraindications for robotic lobectomy were comparable to those reported previously for VATS [14]. Some conditions, such as thoracic dense adhesion, advanced disease and hilar-dense nodal invasion were regarded as relative contraindications.

Patients

A total of 142 patients who underwent RATS lobectomy by a single surgeon from January 2020 to October 2021 were recruited. Among them, 8 cases diagnosed as benign tumors, 6 cases of metastatic lung cancer, 4 cases of small cell lung cancer (SCLC), and 3 cases with previous lung malignancy were excluded. Consequently, 121 patients pathologically diagnosed with NSCLC were included in this study and were divided into the three-port and four-port groups, including 76 cases in the three-port group and 45 cases in the four-port group. Our group first performed robotic lobectomy with the three-arm, four-port approach in May 2019, and the three-arm, three-port approach in in June 2020. The three-port approach is currently the standard procedure in our department, with rare intraoperative conversion to the four-port approach in cases with thoracic dense adhesion or severe calcification of hilar lymph nodes. However, the enrolled patients were all collected after the 50th case to eliminate technical bias, which was far beyond the requirements of the average learning curve of 20 cases [15–17].

The inclusion criteria were as follows: (1) Each patient underwent RATS lobectomy and systematic lymphadenectomy using the three-port or four-port method. (2) The patients were pathologically diagnosed with NSCLC clinical stage IA- IIIA. (3) The patients could tolerate surgery and had normal cardiopulmonary function. (4) No previous medical history of lung surgery.

The exclusion criteria were as follows: (1) Patients with pneumonectomy, wedge resection, segmentectomy, and palliative resection. (2) Patients who had any contraindication for RATS. (3) Abnormality or unhealthy mental conditions detected in the preoperative examinations. (4) Pathological results of SCLC.

Perioperative Preparation

All patients underwent necessary preoperative examinations over 2–3 days to determine the operability and resectability, including hematological tests, urinalysis, stool analysis, serum tumor markers, arterial gas analysis, electrocardiogram, respiratory function, and echocardiography to ensure surgical tolerance. In addition, bronchoscopic examination, brain magnetic resonance imaging (MRI), bone scan, or positron emission tomography-computed (PET-CT) were performed if necessary to exclude distant metastasis. In accordance with the 8th edition of the tumor-node-metastasis (TNM) classifications, the clinical stage of all cases was evaluated. Postoperative complications were classified by the Clavien-Dindo system [18, 19]. Clavien-Dindo grade 1–2 complications were classified as minor complications, and Clavien-Dindo grades 3–5 complications were classified as major complications. The visual analogue score (VAS) was used to measure the intensity of the patients' pain on days 1, 2, and 3 after the operation. This scale was used in the follow-up investigation of various cancers. According to their situation, the point drawn by the patient was consistent with the pain intensity in a straight line, which was recorded after repeated twice.

Surgical procedures

Pulmonary lobectomy was defined as the dissection of an entire lobe and individual interruption of the target pulmonary artery, vein, and lobar bronchus. The patients were administered general anesthesia and contralateral single-lung ventilation was performed with a double-lumen endotracheal tube or endobronchial blocker. The patients were placed in the lateral-decubitus-with-jackknife position to expand the intercostal space (ICS). The da Vinci Xi Surgical System was used for all the surgeries, which was positioned at the patient's head and left side.

The three-port approach was carried out as described in our previous research [5, 6]; the port placement is shown in Fig. 1A. A 0.8-cm camera port incision was made in the 8th intercostal space of the mid-axillary line, which served as the insertion duct for a 30-degree 3D endoscope. The other 0.8-cm port was then set in the same ICS as the camera port at the scapular line for arm 3, which was the robotic arm working channel. A 3–4 cm utility incision was made between the sixth or seventh ribs at the anterior axillary line, which served as an assistant utility port and robotic arm 1 after placing the trocar sleeve. The distance left from arm 1 was sufficient for the bedside assistant to retract the lung, staple, exchange items such as rolled-up sponges and hem-o-lock clips, and cut tissue through a linear stapler. Three ports are placed 8 cm away from each other to avoid collision. Maryland bipolar forceps and a cautery hook were

Fig. 1 The incisions and port placement of the three-port group (**A**) and four-port group (**B**). **A**: The table surgeon and the robotic arm 1 share the same incision. **B**: Port 4 as the utility incision is used by the bedside assistant. A maryland bipolar forceps is placed in robotic arm 1 (surgeon left hand); A 30-degree-angle-down stereoscopic camera is placed in robotic arm 2 (middle arm); A permanent cautery hook is placed in robotic arm 3 (surgeon right hand)

manipulated by the left and right arm, respectively (surgeon's left hand and right hand, arm 1 and arm 2).

The port placement of the four-port approach is shown in Fig. 1B. The camera port position and the auxiliary robotic arm port position were placed in the same ICS as the three-port approach. The assistant incision was performed in the 5th ICS, lateral to the anterior axillary line to reduce arm impingement and interference, and a robotic arm working channel originally in the same incision was created in the 7th ICS between the anterior axillary line and mid-axillary line. Since the port position is close to the heart on the left and the diaphragm attachment on the right, it should be inserted under direct vision from inside the thoracic cavity [20]. The assistant utilizes ring forceps with a rolled-up gauze and aspirater through the utility incision to retract the lung or expose the surgical field.

Table 1 Baseline clinical characteristics of the study subjects

Variables	Three-port group (*n* = 76)	Four-port group (*n* = 45)	*p* Value
Age (years)	61.45 ± 10.44	63.21 ± 11.08	0.876
Sex			0.426
Male	26 (34.2%)	16(35.6%)	
Female	50 (65.8%)	29 (64.4%)	
Smoking history			0.438
Yes	11 (14.5%)	7 (15.6%)	
No	65 (85.5%)	38 (84.4%)	
FEV1% predicted	93.10 ± 11.27	94.22 ± 12.46	0.255
American Society of Anesthesiologists risk class			0.885
I	3 (3.9%)	2 (4.4%)	
II	63 (82.9%)	37 (82.2%)	
III	10 (13.2%)	6 (13.4%)	
IV	0 (0%)	0 (0%)	
V	0 (0%)	0 (0%)	
Tumor size (cm)	2.55 ± 2.75	2.54 ± 1.82	0.975
Tumor location			0.345
left upper lobe	22 (28.9%)	12 (26.7%)	
left lower lobe	12 (15.8%)	4 (8.9%)	
right upper lobe	25 (32.9%)	19 (42.2%)	
right middle lobe	4 (5.3%)	2 (4.4%)	
right lower lobe	13 (17.1%)	8 (17.8%)	
Lobectomy	76	45	0.914
Hypertension	20 (26.3%)	12 (26.7%)	0.771
Diabetes mellitus	5 (6.7%)	4 (8.9%)	0.211
Valvular heart disease	0 (0%)	1 (2.2%)	0.167
Atrial fibrillation	1 (1.3%)	0 (0%)	0.382
Chronic obstructive pulmonary disease	0 (0%)	0 (0%)	-
Coronary artery disease	2 (2.6%)	1 (2.2%)	0.873
Renal disease	0 (0%)	2 (4.4%)	0.135
Liver disease	0 (0%)	2 (4.4%)	0.135

Patients without a definitive preoperative diagnosis underwent intraoperative frozen section diagnosis, and lymph node dissection was conducted if malignancy was confirmed. The management of postoperative pain depended on continuous analgesic pump system, which was inserted through the port between the intrapleural space covering the multi-level intercostal area. After the operation, oral pain killers such as NSAID drugs, ibuprofen (400 mg, three times per day) was initiated at postoperative day 1. After removal of the pump system, we used tramadol at 50 mg, twice per day, which was reduced to 25 mg if the patient developed nausea. Oral pain drugs were gradually reduced during 3 weeks in accordance with standard of care at the department until analgesics were ceased completely. After the operation, all patients were treated with subcutaneous injections of low-molecular-weight heparin for antithrombotic prophylaxis if the drainage fluid was not bright red, which was continued until discharge.

Statistical analysis

The Shapiro-Wilk test was performed to verify if the continuous variables conformed to a normal distribution, in which case they were presented as mean and standard deviation and compared by Student's t-test. Continuous variables not conforming to a normal distribution were compared between groups with the Mann-Whitney U-test. Categorical variables were presented as frequency and percentage and compared by the Chi-square and Fisher's exact test. Considering that the distribution of age, gender, smoking history, pulmonary function, tumor size, and clinical stages were comparable between the 2 groups, propensity score matching was not performed in further analysis. SPSS software was applied for data analysis, and $P < 0.05$ was considered statistically significant.

Results

Baseline clinical characteristics of the three-port and four-port groups

From January 2020 to October 2021, the data of 142 patients who underwent robotic-assisted pulmonary resection in our department were analyzed. Among them, 21 patients were ineligible and 121 patients met all study criteria, including 76 surgeries performed with the three-port approach and 45 surgeries performed with the four-port approach. There was no emergent conversion to open surgery and no operative mortality in either group during hospitalization. The participants' clinical characteristics are detailed in Table 1, followed by statistical analysis of the baseline data, including age, gender, smoking history, pulmonary function, anesthesia risk assessment, tumor size and site, and medical history. There were no significant differences between the two groups in terms of clinical characteristics ($P > 0.05$, Table 1).

Operative features and pathological data

Table 2 presents the operative features and pathological data of the three-port and four-port cohorts. The operative duration was calculated from the first incision to the end of the skin suture. The mean operation time in the three-port group was 9 min shorter than the four-port group (147.32 ± 36.55 vs. 156.83 ± 40.63 min, respectively, $p = 0.510$), and the average intraoperative blood loss was less compared to four-port group (94.34 ± 32.16 vs. 102.73 ± 33.67 ml, respectively, $p = 0.432$). In addition, the postoperative total drainage volume was lower in the three-port group compared to the four-port group (853.42 ± 266.72 vs. 982.63 ± 382.12 ml, respectively, $p = 0.093$). Meanwhile, the three-port group exhibited a shorter postoperative number of days before removing chest tubes compared to the four-port group (2.43 ± 0.65 vs. 2.79 ± 1.42 days, respectively, $p = 0.113$). Similar results were observed in terms of the number of postoperative days before patients were discharged between the cohorts (4.55 ± 1.43 vs. 5.14 ± 1.66 days, respectively, $p = 0.221$). However, these results showed no statistically significant difference. The pathologic cell type of the malignancy and pathological analysis were performed using the 8th edition of the TNM classification, revealing 70 cases of adenocarcinoma and 6 cases of squamous cell carcinoma in the three-port group; pathological staging included 10 cases of stage IA1, 36 cases of stage IA2, 10 cases of stage IA3, 8 cases of stage IIA, 6 cases of stage IIB, and 6 cases of stage IIIA. In the four-port group, there were 41 cases of adenocarcinoma and 4 cases of squamous cell carcinoma; pathological staging included 6 cases of stage IA1, 15 cases of stage IA2, 10 cases of stage IA3, 7 cases of stage IIA, 2 cases of stage IIB, and 5 cases of stage IIIA. No significant difference in pathological type or staging was observed between the two groups ($P > 0.05$, Table 2). In addition, the results of dissected lymph nodes and stations showed no significant difference between the groups ($P > 0.05$, Table 2).

Postoperative pain score and complications

The three-port group performed better than the four-port group in terms of postoperative pain; lower visual analogue scores were obtained with the 3-port approach at days 1, 2, and 3 postoperatively (4.11 ± 0.57 vs. 5.05 ± 0.72, 3.42 ± 0.56 vs. 3.88 ± 0.74, and 2.21 ± 0.45 vs. 2.76 ± 0.66, $P < 0.001$, Table 2). Postoperative complications were observed in 14 patients in the three-port group and 18 patients in the four-port group, and are listed in Table 3. The most common complication was pulmonary air leakage, which might be caused by faulty stapling and severe postoperative cough. Each group had

Table 2 Comparison of perioperative parameters between the two groups

Variables	Three-port group (*n* = 76)	Four-port group (*n* = 45)	*p* Value
Operation time (min)	117.32 ± 36.55	136.83 ± 40.63	0.510
Console time (min)	90 ± 19.35	103 ± 15.65	0.172
Intraoperative blood loss (ml)	94.34 ± 32.16	102.73 ± 33.67	0.432
Chest tube duration (days)	2.43 ± 0.65	2.79 ± 1.42	0.113
Postoperative total drainage volume (ml)	853.42 ± 266.72	982.63 ± 382.12	0.093
Postoperative hospital stay (days)	4.55 ± 1.43	5.14 ± 1.66	0.221
Pathological types			0.549
Adenocarcinoma	70 (92.1%)	41 (91.1%)	
Squamous cell Carcinoma	6 (7.9%)	4 (8.9%)	
Total number of lymph nodes dissected			
N1	6.63 ± 2.44	7.02 ± 2.78	0.646
N2	6.33 ± 1.84	6.72 ± 1.17	0.543
Total number of lymph node stations dissected			
N1	3.31 ± 1.02	3.47 ± 0.94	0.623
N2	3.14 ± 1.21	3.46 ± 1.03	0.247
pTNM stage			0.247
IA1	10 (13.2%)	6 (13.4%)	
IA2	36 (47.3%)	15 (33.3%)	
IA3	10 (13.2%)	10 (22.2%)	
IIA	8 (10.5%)	7 (15.6%)	
IIB	6 (7.9%)	2 (4.4%)	
IIIA	6 (7.9%)	5 (11.1%)	
24 h postoperative VAS pain scores	4.11 ± 0.57	5.05 ± 0.72	<0.001
48 h postoperative VAS pain scores	3.42 ± 0.56	3.88 ± 0.74	<0.001
72 h postoperative VAS pain scores	2.21 ± 0.45	2.76 ± 0.66	<0.001

Table 3 Postoperative morbidity

Variables	Three-port group (*n* = 76)	Four-port group (*n* = 45)	*p* Value
Minor complications (Clavien-Dindo grades 1–2)			
Pulmonary infection	3 (3.9%)	2 (4.4%)	0.735
Pulmonary air leakage	6 (7.9%)	8 (17.8%)	0.327
Atelectasis	2 (2.6%)	3 (6.7%)	0.758
Arrhythmia	1 (1.3%)	1 (2.2%)	0.624
Major complications (Clavien-Dindo grade 3–5)			
Chylothorax	0 (0%)	2 (4.4%)	0.918
Pulmonary embolus	1 (1.3%)	0 (0%)	1.000
Obvious subcutaneous emphysema or pneumothorax	1 (1.3%)	1 (2.2%)	1.032
Required reoperation for bleeding	0 (0%)	1 (0.9%)	1.021

1 patient who suffered from arrhythmia and subcutaneous emphysema or pneumothorax, which resulted from aggravated air leakage. Chylothorax was observed in 2 patients in the four-port group but was not observed in any patient in the three-port group. Reoperation was required in 1 patient in the four-port group due to bleeding from incisions. No patient died during the postoperative hospital stay. All complications were managed successfully by conservative treatment. The occurrence rate of complications demonstrated no significant association with the number of ports (all $P > 0.05$).

Discussion

Over the past few years, a growing number of early-stage non-small cell lung cancers has been detected by high-resolution CT scanning or low-dose CT screening, leading to gradual improvements in people's health consciousness. Lung cancer is one of the most common malignancies worldwide [21]. The optimal procedure is the surgical resection of a single lobe and radical lymph node dissection, which remains the gold-standard surgical approach for NSCLC [22]. Meanwhile, the surgical method has transitioned from traditional open surgery to minimally invasive surgery following improvements in surgical technology. Many observations suggested it happened safely and quickly [4]. The trend has become increasingly obvious over the last twenty years. Within the minimally invasive surgical procedures, VATS and RATS are the main methods of lobectomy and are wildly adopted by thoracic surgeons for lung resection. The first reports of VATS and RATS lobectomy with lymphadenectomy were published in 1994 and 2002 [23], respectively. Almost two decades have passed since the first robotic-assisted lobectomy was performed by Dr Franca Melfi and colleagues, and RATS has rapidly developed into a favorable alternative approach. RATS retains the advantages of VATS and thoracotomy, while eliminating the limitations of both procedures. Dr Zheng [5] reported that during RATS, the operating feeling of the surgeon was similar to thoracotomy surgery in addition to the advantages of 3D view, tremor filtration, a range of internal wrist movements, and an ergonomic console.

Despite the adoption of robotics, there is no agreed-upon port strategy for lung resections. Especially, the ever-growing esthetic demands and desire for satisfactory cosmesis highlight the importance of fewer surgical incisions for thoracic surgeons. The American Association of Thoracic Surgeons Writing Committee defined two surgical approaches, namely the totally port-based approach and the robotic-assisted approach for robotic thoracic surgery in 2017 [24]. Our early robotic-assisted pulmonary resection cases employed the four-port method with three 0.8 cm incisions and a 3 cm additional incision for the assistant surgeon, which was consistent with most reports [25–27]. However, patients were more sensitive to incision number and size than the surgeon's assumption. In 2020, a new three-arm three port method was devised without degrading the quality of RATS using the same incision of robotic arm 1 and assistant hole (Fig. 1), where the anterior trocar is placed at the upper end of the utility incision sleeve, with a 2 cm space left for the assistant to help at the lower end. The space apart from the trocar is adequate for suction, retraction, dissection, palpation of the nodule, and extraction of the large specimen by the surgeon. This approach was modified according to Park [28], Kook [29], and Peng [12], and has the main advantages of the same number and similar mapping of incisions in VATS, while the total number of incisions in four-port RATS is higher. Therefore, our previous surgical experiences of VATS were applicable to RATS, facilitating its implementation.

This study compared and assessed the short-term outcomes of patients who underwent 3-port versus 4-port RATS lobectomy for the treatment of stage I-IIIA NSCLC. In each group, several patients suffered from air leakage, which was mostly attributed to stapler fault and severe cough. The tables presented above revealed no significant difference in operation time, thoracic drainage indwelling time, intraoperative blood loss, postoperative hospitalization time, and pathology outcomes, including histological types and TNM staging between the two groups. Both three-port and four-port RATS were feasible and safe procedures, with a similar curative effect. However, the operation duration of three-port RATS was 117 min on average, which was 19 min shorter compared to four-port RATS. The shorter duration may result from the simpler opening and closure due to one less incision, especially the time taken to secure hemostasis. In addition, the operation time in the three-port group was not significantly prolonged despite extensive adhesions. Notably, one patient was reoperated due to bleeding from the incision (Table 3), which was the incision that was absent in three-port RATS. Although the incision was made under direct vision and the trocar was placed meticulously under the guidance of a robotic camera, the adjacent relationship and proximity between the hole, the pericardium, and the diaphragm increased the risk of accidental damage. Therefore, the number of ports was decreased to optimize port strategy, thereby minimizing iatrogenic injuries and catastrophic bleeding.

In addition, lymphadenectomy is an aspect that cannot be ignored, as it is an indispensable factor affecting the prognosis of NSCLC [30]. A previous study has demonstrated the association between radical lymph node dissection, which is superior to lymph node sampling, and more accurate staging [31]. In our hospital, the standard pulmonary resection consists of lobectomy and systematic lymph node dissection, following the guidelines of lung cancer treatment. All cases in both groups met the criteria for complete resection. The three-port group and the four-port group showed no significant difference with regard to the number of dissecting lymph nodes and dissecting stations. To date, many reports have assessed the lymph nodes removed under the robotic approach. In 2021, Huang et al. [32] reported the outcomes of 685 patients with stage I-IIIA who underwent robotic lobectomy. They found that the number of dissected lymph nodes was 14.87 ± 2.05 and stations were 6.19 ± 1.01 among these patients, which is similar to the results reported in the present study, indicating that lymph node dissection in our department was thorough enough. In 2023, Anna et al. [30] compared the outcomes of 246 pulmonary resections with systematic lymph node dissection for clinical stages I–II NSCLC. The total number of dissected lymph nodes and stations was significantly higher in RATS. No negative repercussion was observed in the three-port group in relation to lymphadenectomy, which might be explained by the gained experience in four-port RATS, facilitating the transition to the three-port procedure. Although the assistant hole and arm port passed through the same working channel, the mobility of the three robot arms is completely independent and unaffected.

Furthermore, the two groups exhibited significant differences in terms of postoperative pain. From the postoperative VAS pain score, the three-port group performed better than the four-port group. With the time ongoing, we noticed that the degree of pain alleviation became apparent under administration of various drugs. If this was not sufficient, the oral dose of analgesics was increased and an analgesic pump was started, indicating that RATS can still be a painful surgical procedure. Previous studies have pointed out that multiple surgical incisions may lead to aggravation of postoperative pain in both VATS [33] and RATS [29]. Likewise, the general opinion in the thoracic surgery community is that the number of ports used for RATS lobectomy could affect the amount of pain, but the quality of evidence for this assumption is low. Fewer ports are better and RATS lobectomy has even been performed with bi- [34] or uni-port [35] approaches in few medical centers. In our report, the lower immediate postoperative pain may be attributed to the absence of an anterior port in the three-port group, preventing intercostal nerve constriction and injury. On the other hand, due to the disadvantage of lack of force feedback under robotic surgery, patients are more likely to experience rib fractures if the robotic arms are moved extensively, which may cause severe postoperative pain.

Nevertheless, the limitations of the current study should be acknowledged. First, the study was limited by its retrospective nature and a single-center setting, with a relatively small number of enrolled patients. Prospective studies or randomized controlled clinical studies involving more patients in a multi-center setting are required to further prove the three-port procedure as an alternative to the pre-existing four-port procedure. Second, only the perioperative results of the robotic-assisted lobectomy were evaluated, whereas the long-term survival results and oncological outcomes were overlooked, which need further research. Third, despite the fact that we attempted to increase the number and the consistency of the two groups to improve the comparisons, the risk of selection bias remains. Finally, this study only compared with the four-port RATS to the three-port RATS, and other relevant comparisons such as VATS lobectomy with fewer ports should be conducted.

Conclusions

In summary, the three-port and the four-port strategies for robot-assisted lobectomy were compared, proving to be safe, effective, and efficient approaches. Based on our results, the three-port RATS, with fewer incisions, improves cosmetic results, reduces postoperative pain, and does not impact clinical outcomes. This documented port strategy is a strength of this paper. While robust data comparing different port placements in robotic lobectomy are rare, this paper provides a reference from which thoracic robotic surgeons can adapt our three-port strategy to individual patients as appropriate. The approach can be further expanded, improved, and refined.

Abbreviations

NSCLC	Non-small cell lung cancer
SCLC	Small cell lung cancer
RATS	Robot-assisted thoracoscopic surgery
VATS	Video-assisted thoracoscopic surgery
CT	Computed tomography
MRI	Magnetic resonance imaging
PET/CT	Positron emission tomography/Computed tomography
ICS	Intercostal space
TNM	Tumor-node-metastasis
LN	Lymph node
VAS	Visual analogue score

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Author contributions

CY designed the study and FY drafted the manuscript. LC helped in gathering patient information and analyzed the data. QW obtained the image data. HW provided the pathological results. All authors read and approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional ethical committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. And all experimental protocols in the manuscript were approved by Soochow University. Informed consent was obtained from all individual participants included in the study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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